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The Russian Wheat Aphid
Eighth Annual Report

1986 - 1996

The Russian Wheat Aphid:
Ten Years Later

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Research Laboratory
Stillwater, Oklahoma

PSWCRL Prog. Rep. 96-001

Contents

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Material reported herein has been previously cleared for release by individual contributors. For additional information on a particular research effort, contact the contributing scientist(s).

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Introduction

This year marks the 10th Anniversary of the detection of the Russian wheat aphid in the United States. In March 1986, ARS researchers in Stillwater, OK, received a call from a Texas A&M area entomologist about "...these aphids out here in this wheat, these things that apparently don't have any cornicles, they kind of look like a greenbug and they've got these 2 processes sticking off the rear end." The history of discovering this new pest of wheat and barley in Bailey County, Texas, was meticulously outlined in a colorful documentary by Dr. Pat Morrison of Texas A&M University at the First Russian Wheat Aphid Conference[1] in 1987 in Guymon, OK. This, along with other information in the proceedings of that meeting, is highly recommended for those interested in the early history of the RWA in the United States. More recent information about this pest was compiled in an extensive RWA bibliography.[2] In addition, an RWA symposium was held at the 1994 Annual Entomological Society of America Meetings in Dallas, TX. The proceedings of that meeting will be published as an Entomological Society of America Thomas Say Publication within the year and will be the most recent comprehensive information available on the RWA.

Since that first discovery near Muleshoe, TX, in 1986, the RWA has spread rapidly to the other major wheat- and barley-producing areas of the United States. Serious infestations and economic losses have occurred in 17 states west of the 100th meridian (Fig. 1). The Russian Wheat Aphid Task Force of the Crops and Soils Committee, Great Plains Agricultural Council, has conducted annual economic impact studies of the pest since 1987. Total losses have ranged from $12 million in 1991 to over $274 million in 1988. This is the most comprehensive continuous economic impact information for any small grain pest in the United States. The continuation of this annual study was threatened with the recent dissolution of the Great Plains Agricultural Council; however, members of the WRCC-66 RWA Aphid Biology and Control Committee have agreed to assume the responsibility for it.

The latest economic impact data by Patrick and Amosson[3] show that estimated yield losses attributed to the RWA in the western United States during the 1993-94 crop year were 11,429,645 bushels, with an estimated value of $36,035,000. This is the fourth highest loss year on record, and is more than twice the 1993 losses. During the 1993-94 crop year, 960,943 acres were

[1]Coppock, S. and B. Massey (eds). 1988. Proceedings of the First Russian Wheat Aphid Conference. Okla. State Univ. Coop. Ext. Serv. Bull. E-875.

[2]Poprawski, T.J., N.L. Underwood, G. Mercadier, and F. Gruber. 1992. *Diuraphis noxia* (Kurdjumov) - A bibliography on the Russian wheat aphid, 1886-1992. U.S. Dep. Agric., Agric. Res. Serv., Ithaca, NY.

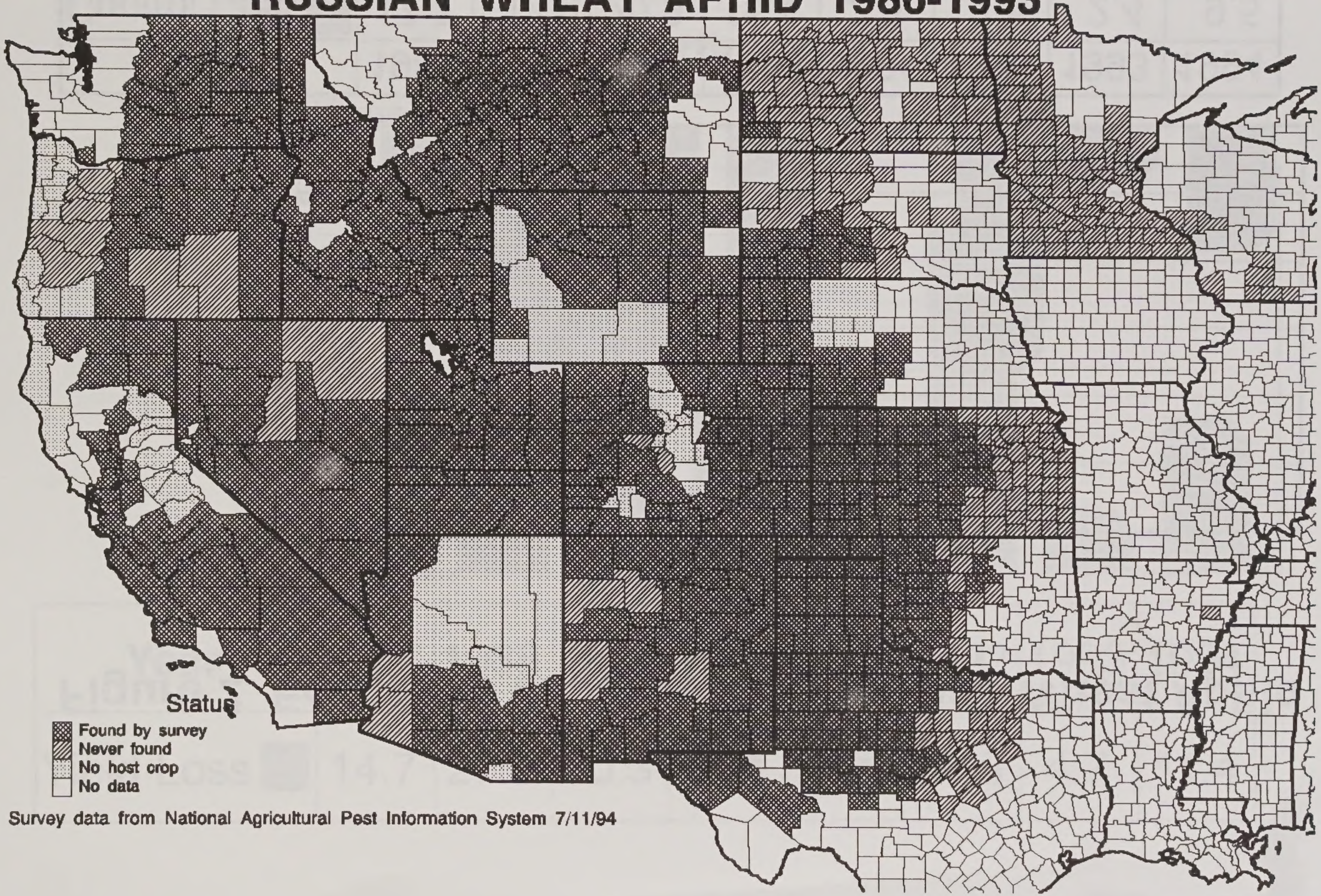
[3]Patrick, C.D. and S. Amosson. 1996. Economic impact of the Russian wheat aphid in the United States: 1993-94. Texas A&M Univ. (In press)

treated with insecticides for the RWA at a cost of $9,476,000. Estimates of cumulative losses for 1987-94 are $478.1 million in direct loss (control costs, yield loss, and grazing loss) and $508.5 million in indirect loss (ripple effects sustained by the regional economy)--a total loss of over $986 million. Additional information about the economic impact to the RWA in the western United States is presented in Figures 2 and 3. The RWA also causes other losses, but they are not as tangible and thus cannot be included here. For example, the production of feed barley in heavily infested RWA areas has virtually come to a standstill because pesticide treatments are not economically feasible for this crop which has a very low profit margin. In 1994, average aerial treatment costs for RWA ranged from $8/acre in Washington to $11/acre in Arizona,[3] an expense that is a heavy burden for most feed barley growers. Another intangible loss is the unknown effects that wide-scale pesticide applications for RWA control have on the environment. For these reasons, much of the ARS RWA research program is devoted to developing "natural" management methods, including the development of RWA-resistant wheat and barley germplasm lines, and the study of natural enemies as potential management strategies.

This is the eighth annual report of research progress on the RWA by the Agricultural Research Service of the USDA. As the report indicates, and as mentioned in the preceding paragraph, our research is focused on natural control methods, with a central objective of evaluating the combined effects of RWA-resistant wheat and barley, natural enemies, and established cultural practices on RWA population dynamics, economic thresholds, and crop yield. Our research directly supports the USDA mandate that 75% of U.S. cropland will be in an IPM system by the year 2000. Whether an individual RWA project is involved with molecular genetics, non-cultivated hosts, or GIS, our overall goal continues to be the development of improved pest management systems for the RWA.

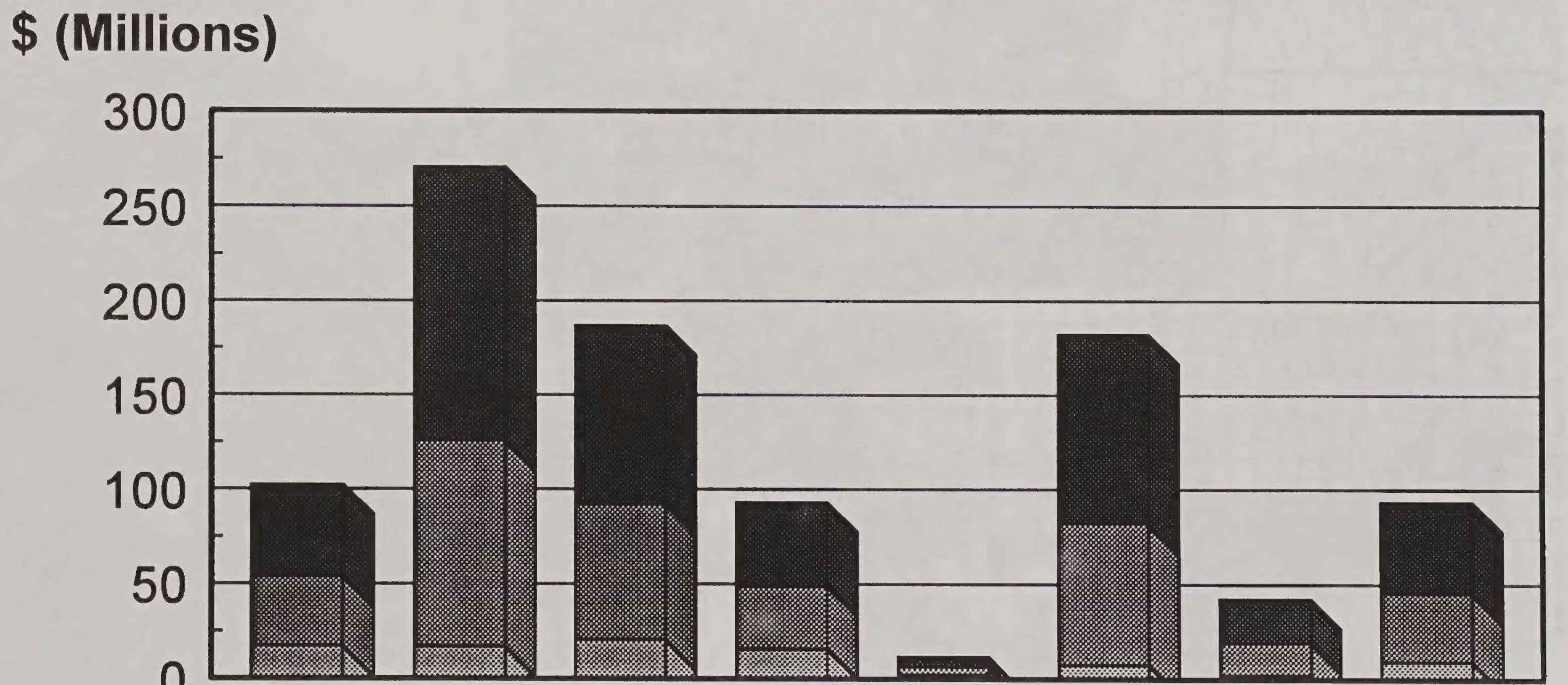
This report is intended as a brief update on the advances in ARS RWA research that have taken place during the past year. Many of our projects are cooperative with organizations including other ARS scientists and locations, as well as scientists from state agricultural experiment stations and USDA-APHIS. These combined efforts provide an excellent model of a cooperative research endeavor and greatly increase the probability of successfully managing the RWA on a regional basis. Space limitations for this report dictate brevity. Additional information about the RWA or specific projects may be obtained directly from the scientists listed in the individual research reports.

RUSSIAN WHEAT APHID 1986-1993



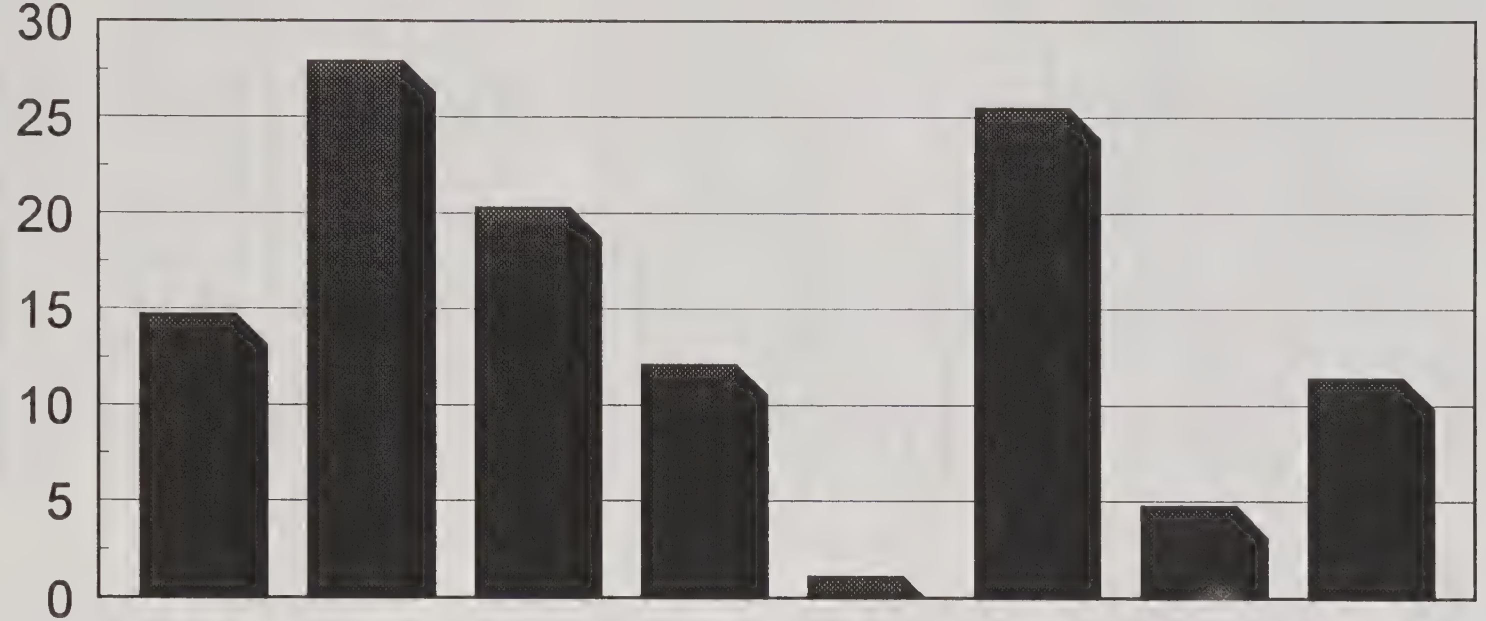
Survey data from National Agricultural Pest Information System 7/11/94

Figure 2. Economic Impact of the Russian Wheat Aphid



Year	1987	1988	1989	1990	1991	1992	1993	1994
Control Cost	17.2	17.0	20.9	15.4	2.5	7.6	2.4	9.5
Yield Loss	36.6	108.9	71.2	33.4	3.9	74.8	17.1	36.0
Indirect Loss	48.7	144.8	94.7	44.5	5.3	99.7	22.8	47.9

Figure 3. Impact of Russian Wheat Aphid on Small Grain Production



Year	1987	1988	1989	1990	1991	1992	1993	1994
Yield Loss	14.7	27.9	20.3	12.1	1.1	25.5	4.7	11.4

Stillwater, Oklahoma

Alternate Hosts for Russian Wheat Aphid

Mission: The mission of the Alternate Hosts program is to identify and characterize RWA-resistant germplasm lines that may serve as breeding resources for both cool- and warm-season cereals and turf, range, and conservation grass species.

Personnel:

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Report:

The western wheat aphid (WWA), *Diuraphis tritici* (Gillette), a closely related species of the RWA, shares a similar distribution pattern in the United States. While RWA is considered a perennial economic pest of wheat, WWA is at most an occasional economic pest. Yet under controlled conditions we have determined that WWA is significantly more deleterious to the yield potential and yield components of wheat. Does WWA have the potential to become as serious a pest as RWA, and if so, under what conditions?

Previous studies have shown that the economic importance of RWA depends in part on its ability to use plant species as alternative and oversummering hosts. We studied the survival and reproduction of WWA on numerous cool- and warm-season grasses, legumes, and forbs, and also compared WWA with RWA on some common *Bromus* spp. and *Agropyron* spp. to see if the two aphid species differ in their reproduction and survivorship on the same grass species. Although the WWA was able to reproduce and survive on the plants tested, its natality was significantly lower than that of RWA. In addition, we found the WWA more difficult to rear under identical environmental conditions, indicating that WWA is much more sensitive to its environment than is RWA.

It appears from our preliminary tests that WWA may not easily become the menace that RWA is. Important baseline data obtained from our studies can be used to monitor for virulent biotype development.

Publications Since Last Report:

Kindler, S.D., T.L. Springer, and K.B. Jensen. 1995. Detection and characteristics of the mechanisms of resistance to Russian wheat aphid (Homoptera: Aphididae) in tall wheatgrass. J. Econ. Entomol. 88:1503-1509.

Stillwater, Oklahoma

Host Plant Resistance and Small Grain Germplasm Enhancement

Missions: The mission of the Host Plant Resistance program is to identify resistance sources, study the nature of this resistance, and cooperate with the Small Grain Germplasm Enhancement program in the development and release of RWA-resistant small grain germplasms. The mission of the Small Grain Germplasm Enhancement program is to identify, characterize, and introgress genes conferring RWA resistance for small grain germplasm enhancement.

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Report:

Wheat - Topcrossing of RWA-resistant wheat selections to high-performance recurrent parents continued. Efforts are ongoing to develop RWA-resistant wheat lines for all market classes that are grown in areas where RWA is a problem. Over 400 winter wheat lines derived from crosses with seven different sources of RWA resistance were planted in the field for evaluation in Stillwater prior to germplasm release. Genetic diversity studies continued, utilizing intercross populations. Thirty-five advanced lines developed from four different RWA resistance sources were planted for seed increase and evaluation in preparation for entering the germplasm release stage. New sources with very high levels of RWA resistance are now being incorporated into the crossing and genetic evaluations programs. Several cooperative projects are ongoing to provide screening and evaluation tests for various public and commercial wheat breeders. RWA resistance testing continues on wheat X triticale cross populations. Several agronomically acceptable wheat lines with high levels of resistance have been identified and are being cytologically characterized.

Barley - RWA-resistant germplasm line STARS-9577B will be released to breeders in the spring of 1996. STARS-9577B is a six-row spring barley with a greenhouse seedling resistance rating of 3 on Webster's scale of 1-9. Two years of field study in Wyoming has shown this line to have no significant yield reduction under artificial field infestations. Genetic analysis has shown RWA resistance of this line to be under the control of two genes. Both genes appear to be dominant with recessive epistasis. This inheritance differs from the inheritance in RWA-resistant barley germplasm line STARS-9301B. The primary mechanism of resistance in STARS-9577B appears to be tolerance. A total of 217 crosses were made in the greenhouse in 1995 to obtain populations for genetic studies and for prebreeding purposes. One hundred twenty-one BC's were made for prebreeding/future genetic studies, 57 F_1's and/or reciprocal F_1's between resistant lines and susceptible cultivars were made for prebreeding/genetic studies, 21 F_1's between resistant lines were made for future tests for genetic diversity, and 18 test crosses were made between the F_1 of two resistant lines a susceptible cultivar for genetic diversity studies. One hundred eleven F_2 populations were increased for future genetic analysis, as well as 300 F_2-derived F_3 families for each of 16 populations. Parents, F_1, F_2, and BC(s) to both parents as well as 300 F_2-derived F_3 families have been evaluated for two resistant lines. F_3 analysis indicates multiple gene control for both of these lines. Interpretation of gene action from the F_1, reciprocal F_1, F_2, and BC to both parents has yet to be completed.

Publications Since Last Report:

Baker, C.A., J.A. Webster, and D.R. Porter. 1995. Inheritance and mechanisms of Russian wheat aphid (RWA) resistance in wheat PI 245462. Agron. Abstr., Am. Soc. Agron., Madison, WI. p. 88.

Miller, H.L., and D.R. Porter. 1996. A technique to quantitatively measure the leaf streaking symptom of Russian wheat aphid infestation. Crop Sci. (In press)

Mornhinweg, D.W., D.R. Porter, and J.A. Webster. 1995. Inheritance of Russian wheat aphid resistance in spring barley. Crop Sci. 35:1368-1371.

Mornhinweg, D.W., D.R. Porter, and J.A. Webster. 1995. Inheritance of RWA resistance in barley germplasm line R006. Agron. Abstr., Am. Soc. Agron., Madison, WI. p. 88.

Mornhinweg, D.W., D.R. Porter, and J.A. Webster. 1995. Registration of STARS-9301B barley germplasm resistant to Russian wheat aphid. Crop Sci. 35:603.

Mornhinweg, D.W., D.R. Porter, and J.A. Webster. 1995. Russian wheat aphid resistance in barley: An update. Proc. 30th Barley Imp. Conf., Minneapolis, MN. pp. 82-85.

Porter, D.R., H.T. Nguyen, and J.J. Burke. 1995. Genetic control of acquired high temperature tolerance in winter wheat. Agron. Abstr., Am. Soc. Agron., Madison, WI. p. 88.

Porter, D.R., H.T. Nguyen, and J.J. Burke. 1995. Genetic control of acquired high temperature tolerance in winter wheat. Euphytica 83:153-157.

Stillwater, Oklahoma

RWA-Host Plant Interaction and Insect Genetics

Missions: The mission of the RWA-Host Plant Interaction program at Stillwater is to characterize plant physiological and biochemical responses to RWA attack in resistant and susceptible germplasm to identify superior metabolic systems, pathways, or individual components critical to genetic resistance. The mission of the Insect Genetics program is to conduct national and worldwide biotypic and genetic studies on the RWA and its parasitoids.

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Report:

Studies were initiated to determine the genetic diversity of RWA populations from distinct habitats over a wide geographic area in eastern Colorado. RWA were collected bimonthly from geographically isolated field plots established along roadsides, margins of cultivated wheat and barley fields, and within Conservation Reserve Program acreage near cereal fields that were infested with aphids. The amount of genotypic diversity among and between these RWA populations will be evaluated using genetic fingerprinting techniques.

RWA populations that were monitored throughout the year showed the importance of non-cultivated volunteer wheat and barley as well as crested wheatgrass and Canada wild rye as over-summering host-bridges during the intervening periods between cereal crops. Studies of RWA population dynamics on selected non-cultivated host species were initiated in the fall of 1995 in replicated small-plot nurseries. Variable life table analyses will be conducted on naturally occurring aphid populations throughout the year. Field samples of RWA from geographically isolated populations were collected bi-monthly and will be genetically fingerprinted to aid in ascertaining the amount of genotypic diversity among and between populations.

A genomic library of RWA was constructed from which the ribosomal RNA cistron was cloned. The rRNA cistron was subcloned into a Bluescript vector and is currently being mapped using restriction enzyme digests and hybridization with greenbug

probes. There appears to be much homology in the coding regions between the greenbug and RWA; however, as expected, the intergenic spacer (IGS) shows no homology. Thus far, we have identified an unusual *Eco*R1 polymorphism in the 18S gene in RWA. The polymorphism has been confirmed by probing genomic DNA isolated from RWA maintained in a laboratory colony that was originally established from field collections in the USA. However, limited surveys of field populations in 1994 and 1995 did not reveal the polymorphism. This may be a rare or poorly fit genotype. Because of the parthenogenetic nature of RWA populations in the USA, finding a polymorphism such as this indicates that more than one RWA genotype has been introduced into the USA. Selected subclones of the RWA rRNA cistron will be sequenced and PCR primers developed for the *Eco*R1 polymorphic site and the IGS. These will be used to further evaluate RWA populations in the USA for genetic diversity.

CGA 215944 and Gaucho® (imidacloprid) are newly developed insecticides with primary activity on sucking insects and will likely become available for use against aphids in cereal agroecosystems. At low concentration these insecticides have been reported to have antifeedant effects on aphids and, excluding host mortality, are touted as being innocuous to natural enemies. We evaluated the effect of systemically applied, low concentrations of these aphicides on the feeding behavior of the RWA on wheat using electronic feeding monitors. Aphids began surviving 15 days after treatment with CGA 215944 (soil drench, 10 g ai/liter) and 45 days after planting on plants grown from seed dressed with Gaucho (1 fluid oz/cwt). Following these periods of acute toxicity, CGA 215944 exhibited antifeedant effects on RWA that were expressed by increases in the frequency and duration of non-ingestion feeding behaviors. Aphids on plants treated with CGA 215944 spent significantly more time in nonprobing activities and had a much higher frequency of leaf penetration spikes, followed by significantly shorter periods of phloem ingestion. Immediately after the period of acute aphid toxicity, there were no substantial carryover effects from CGA 215944 or Gaucho on the tritrophic relationship between host plant, RWA, and *Diaeretiella rapae* McIntosh.

Publications Since Last Report:

Burd, J.D., R.A. Butts, N.C. Elliott, and K.A. Shufran. 1996. Russian wheat aphid biology and host-plant interactions. Thomas Say Publ. Entomol. (Accepted)

Burd, J.D., and N.C. Elliott. 1995. The effect of Russian wheat aphid feeding on chlorophyll a fluorescence induction kinetics of resistant and susceptible cereals. Eur. J. Plant Pathol. Abstr. XIII Int. Plant Prot. Congr. Abstr. 1006.

Burd, J.D., and N.C. Elliott. 1996. Changes in chlorophyll a fluorescence induction kinetics in cereals infested with Russian wheat aphid (Homoptera: Aphididae). J. Econ. Entomol. (In press)

Burd, J.D., N.C. Elliott, and D.K. Reed. 1996. Feeding behavior of Russian wheat aphids following exposure to the aphicides Gaucho and CGA-215944 and their potential effect on a Hymenopterous parasitoid. Southwest. Entomol. (Submitted)

Burd, J.D., J.A. Webster, G.J. Puterka, R.P. Hoxie, and S.G. Wellso. 1996. Effect of Russian wheat aphid on nonstructural carbohydrate profiles of wheat seedlings. Southwest. Entomol. (In press)

Stillwater, Oklahoma

Biological Control

Mission: The mission of the Biocontrol program at Stillwater is to develop strategies in the laboratory, greenhouse, and field for maximum utilization of natural enemies (exotic, naturalized, and endemic) in RWA-infested cereals and grasses.

Personnel:

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Report:

The natural enemy impact evaluation studies initiated in southeastern Colorado in 1994 were continued in 1995. The scope of the studies was expanded to include a RWA-resistant winter wheat cultivar 'Halt' in addition to the susceptible cultivar 'Lamar' used in 1994. Results from 1995 suggest that exotic parasitoids that were established in the region in 1993 still occur in the field at very low population densities, and thus, exert minimal impact on RWA populations. However, native parasitoids and aphid predators may exert greater impact on RWA populations in Halt than in the susceptible wheat variety, suggesting that host plant resistance may lead to improved regulation of RWA populations by natural enemies.

Progress toward development of a computer model for simulation of the region-wide population dynamics of the RWA included acquisition and classification of Landsat MSS data for the portion of the Great Plains from south Texas to Wyoming, and development of process models for simulating RWA population dynamics in fields of winter wheat and intermediate and crested wheatgrasses. Preliminary results of validation studies suggest that temperature, rainfall, and strong winds are important abiotic factors, and that wheat plant growth stage is an important biotic factor contributing to the aphids' population dynamics. Native natural enemies appear to exert minimal impact on RWA populations during most of the growing season, but may exert some impact during heading and later stages of wheat plant growth. Exotic natural enemies were too rare to warrant inclusion in models.

We compared removal with quadrat sampling to determine if removal sampling provided useful estimates of population density of adult and larval coccinellids in winter wheat. We also determined the utility of timed count and sweepnet sampling for estimating adult and larval coccinellid densities. Removal sampling provided accurate estimates of population density for adults of most species, but consistently underestimated larval density. Regression models were developed to convert estimates of relative to estimates of absolute population density. Models incorporated variables such as the number of tillers per 0.3 m, wheat plant growth stage, plant height, and the number of aphids per tiller. A 25-sweep sample with a standard sweepnet was the most efficient unit (smallest coefficient of variation per unit cost) for estimating adult coccinellid density from among those studied. The efficiency of two 12-minute removal samples from within a 25-m^2 area, a 6-minute count, and complete enumeration of coccinellids in a m^2 quadrat, while less efficient than the 25-sweep sample, did not differ significantly from one another. The 25-sweep sample and 6-minute count were the most efficient units for estimating larval density.

A mathematical relationship between the mean and variance of the number of lady beetles per m^2 in a wheat field was obtained using Taylor's power law. A sequential sampling plan was developed to estimate the number of lady beetles per m^2 with constant average statistical precision (standard error/mean) using an equation relating the number of lady beetles per m^2 to the number of lady beetles per 1-minute count and the Taylor's power law relationship. The plan involves conducting a series of 1-minute counts while walking through a field at a constant velocity of 10 m per minute. After each 1-minute count, sequential sampling stop-lines are consulted to determine if the specified level of precision has been achieved.

Publications Since Last Report:

Elliott, N.C., J.D. Burd, and G.L. Hein. 1995. Russian wheat aphid ecology in the Great Plains. Proc. Southwest. Rocky Mt. Div., Am. Assoc. Adv. Sci. 31:32-33.

Elliott, N.C., J.D. Burd, S.D. Kindler, B.W. French, and D.K. Reed. 1996. Temperature effects on development of three cereal aphid parasites (Hymenoptera: Aphidiidae). Great Lakes Entomol. (In press)

Elliott, N.C., G.L. Hein, J.D. Burd, and J.H. Lee. 1995. The population dynamics of the Russian wheat aphid in Great Plains agricultural landscapes. Suppl. Bull., Ecol. Soc. Am. 76:74.

Elliott, N.C., G.L. Hein, M.R. Carter, T.O. Holtzer, and J.D. Burd. 1996. Russian wheat aphid ecology and modeling in Great Plains agricultural landscapes. *In* S. Quisenberry and F. Peairs (eds.) A Response Model for an Introduced Pest--The Russian Wheat Aphid. Thomas Say Publ. Entomol. (Submitted)

Elliott, N.C., and G.J. Michels, Jr. 1996. Estimating aphidophagous coccinellid populations in alfalfa. Biol. Control (Submitted)

Elliott, N.C., G.J. Michels, Jr., and R.W. Kieckhefer. 1996. Sequential sampling to estimate coccinellid populations in wheat with fixed precision. Biol. Control (Submitted)

Michels, G.J., Jr. and N.C. Elliott. 1996. Estimating aphidophagous coccinellid populations in winter wheat. Environ. Entomol. (Submitted)

Brookings, S. Dakota

RWA-Host Plant Interaction

Mission: The mission of the RWA-Host Plant Interaction program at Brookings is to develop and evaluate sustainable production systems that enhance environmental quality and provide health, safety, and profitability for agriculture in the Northern Great Plains, with emphasis on crop and pest management.

Personnel:

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Report:

No activities pertaining to RWA were reported for 1995. Following Dr. Kieckhefer's retirement in January 1996, it is anticipated that research efforts at Brookings will shift to other insect pests.

Publications Since Last Report:

Kieckhefer, R.W., J.L. Gellner, and W.E. Riedell. Evaluation of the aphid-day standard as a predictor of yield loss caused by cereal aphids. Agron. J. (In press)

Riedell, W.E., and R.W. Kieckhefer. 1995. Feeding damage effects of three aphid species on wheat root growth. J. Plant Nutr. 18:1881-1891.

Beltsville, Maryland

Biosystematics

Mission: The mission of the Biosystematics program is to provide identifications and verifications for RWA and its natural enemies.

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Report:

Dr. Stoetzel continued to provide identifications and verifications for *Diuraphis noxia* (Mordvilko). No other activities regarding RWA were reported for 1995.

Ithaca, New York

Biological Control

Mission: The mission of the Biological Control program at Ithaca is to develop fungal pathogens of RWA, devise strategies for the introduction of fungi for RWA control in the field, and provide taxonomic support to other scientists studying RWA pathogens.

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Report:

In 1995, a study was done to compare the efficacy of *Paecilomyces fumosoroseus* conidia produced on solid and liquid substrates for adult RWA. Isolates used were ARSEF 4491, ARSEF 4501, and Mycotech 612. Preparations tested included aerial conidia produced on SDAY and three preparations of spores grown in a liquid amino-acid-glucose-salts medium: freshly harvested spores, freeze-dried spores, and spores dried in air with the addition of a filtration agent. Spore suspensions were sprayed on aphids at a concentration of approximately 50 spores/cm^2. Controls were included for the suspending medium, the liquid culture medium, the freeze-drying protectant, and the air-drying filtration agent. Mortality of aphids after 5 days was compared after adjusting for the number of colony-forming units obtained for each preparation. Potency ratios were estimated in relation to standardized aerial conidia of ARSEF 4461. Highest potency ratios were obtained for freshly harvested spores from liquid medium and for air-dried spores. ARSEF 4501 showed the most variability and Mycotech 612 the least. Spores produced in submerged culture infected hosts more quickly than aerial conidia. This study demonstrates that spores of *P. fumosoroseus* produced in submerged culture are efficacious toward this target insect.

In cooperation with researchers at the University of Idaho, Mycotech Corporation, and ARS-Peoria, we tested both *Beauveria bassiana* and *P. fumosoroseus* against RWA in the field in Aberdeen, ID. We infested two varieties of spring-planted wheat, 'Centennial' (RWA-susceptible) and IDO488 (RWA-resistant). Our five treatment groups consisted of unsprayed, control-sprayed, Mycotrol WP (*B. bassiana*), *P. fumosoroseus* aerial spores, and *P. fumosoroseus* spores produced in submerged culture (called "blastospores"). We applied treatments twice, at 5-day intervals, and monitored a variety of

variables following application. We verified the deposition of fungal spores on leaf surfaces and found infected aphids in treated plots. Most important, there was a significant drop, compared with controls, in live aphid levels at 6 weeks after treatment in Centennial. There was also a decrease in aphid populations in IDO488, although the difference from controls was not statistically significant. The greatest decrease in populations was observed among aphids treated with the submerged-culture spores of *P. fumosoroseus*. Infection of aphids by fungi in the original spray inoculum probably occurs within 1 week. Given the extremely high aphid populations we treated in 1995, an evident decline in aphid numbers took longer to become apparent. We plan to expand and improve on these experiments in 1996.

In corresponding laboratory assays, we are currently testing the relative susceptibility to fungal infection of aphids reared on aphid-resistant and aphid, susceptible hosts. Preliminary results indicate clearly lower infection rates by both *B. bassiana* and *P. fumosoroseus* for aphids on resistant wheat (IDO488) in comparison with susceptible wheat (Centennial) and susceptible barley (8-12).

A high degree of diversity among isolates of *P. fumosoroseus* was evident from genetic fingerprints obtained from RAPD-PCR and vegetative incompatibility of nitrate non-utilizing mutants. Among eight isolates of *P. fumosoroseus*, those with higher efficacy toward host insects also germinated significantly more rapidly in vitro. Further studies to verify speed of germination as a virulence factor are underway.

Publications Since Last Report:

Vandenberg, J.D. 1996. Standardized bioassay and screening of *Beauveria bassiana* and *Paecilomyces fumosoroseus* (Deuteromycotina: Hyphomycetes) against the Russian wheat aphid (Homoptera: Aphididae). J. Econ. Entomol. (Submitted)

Cantone, F.A., and Vandenberg, J.D. 1995. Genetic variability within a worldwide collection of isolates of *Paecilomyces fumosoroseus*. Proc. Soc. Invertebr. Pathol. 28:11.

Vandenberg, J.D., Jackson, M.A., and Lacey, L.A. 1995. Efficacy of aerial and submerged conidia of *Paecilomyces fumosoroseus* for Russian wheat aphid adults. Proc. Soc. Invertebr. Pathol. 28:62.

Montpellier, France

Biological Control

Mission: The mission of the Biological Control program at the European Biological Control Laboratory in Montpellier is to collect, study, and import natural enemies and entomopathogens of the RWA, and to study their interactions with other natural enemies of RWA.

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Report:

During the past year we have focused our research on several aspects of the interaction of entomopathogenic fungi, the RWA, and *Aphelinus asychis*, a common parasitoid of *Diuraphis noxia*. The acute and sublethal effects of *Paecilomyces fumosoroseus* (*Pfr*) on adult female *A. asychis* were studied under conditions of low and high humidity at 24°C. When the parasites were exposed to four dosages of *Pfr* ranging from 3.75 to 3.75 X 10^3 conidia/cm^2 in humidities of approximately 50% RH and over 90%, respective ranges of mortality of 20-33 and 33-88% were observed. The effect of treatment with *Pfr* at 5.2 x 10^4 spores/cm^2 on foraging behavior at low and high humidities was studied with video image analysis 24, 48, 72, and 96 hours after exposure to the fungus. There was no significant difference between control females and those treated with *Pfr* in terms of average distance walked when the insects were incubated at 50% RH. When incubated at 90+% RH, a significant difference in average distance covered was observed 4 days after exposure to the fungus. Significantly higher mortality was observed in treated females that were incubated at the higher humidity. When total distance covered by the treated females accounted for mortality (i.e., total distance covered by all surviving females), the females incubated at the higher humidity for 96 hours covered only 60% of the distance observed for treated females held at the lower humidity.

Aphelinus asychis and *P. fumosoroseus* were evaluated separately and in combination against confined populations of *D. noxia* under field conditions. Groups of 10 infested barley plants were treated in a spray tower with either 10 ml of a fungal suspension (1.7 x 10^7 conidia/ml) [with and without incubation for 24 hours under ideal conditions (*Pfr*, *Pfr*(24h), respectively)], or four female *A. asychis* (*Aa*), or both fungus and parasitoids (*Pfr+Aa*). Insects treated with *P. fumosoroseus* and later exposed to *A. asychis* and those exposed only to the parasitoids responded with higher mortality at 7 and 10 days post-treatment than controls or those receiving only the fungus. Laboratory-confirmed mycosis in cadavers of *D. noxia* recovered from plants that had received fungal treatments ranged from 24.4 to 31.9% (*Pfr*); 26.6 to 43.3% (*Pfr*(24h)) and 27.7 to 34.5% (*Pfr+Aa*). No patently infected cadavers were recovered from the field. The total number of living aphids per plant was significantly lower in the treatments involving *A. asychis* than in all other treatments and controls throughout the test. Significantly lower numbers of *D. noxia* relative to controls were also observed 13 days post-treatment for the *P. fumosoroseus* treatment that was first incubated in the lab. At the termination of the test 13 days post-treatment, the density of aphids on plants treated with *Pfr+Aa*, *Aa*, *Pfr*(24h), and *Pfr* was 38.2, 43.1, 70.5, and 91.9% of that observed on control plants, respectively. Significant differences in the percentages of aphid age groups were observed between treatments involving *A. asychis* and all other treatments and controls 13 days post-treatment; there was a significant reduction of the percentage of younger instar and relative increase in older instars for the treatments involving *A. asychis*. There was no significant difference between the number of mummies observed on plants receiving *A. asychis* only or in combination with the fungus. The height of the plants was not influenced by treatment nor the sampling date. However, the dry weight of plants receiving both *A. asychis* and *P. fumosoroseus* was significantly greater than controls 13 days post-treatment. These studies reveal an additive effect of *P. fumosoroseus* and *A. asychis* with regard to aphid control with no detrimental effects on the percentage of parasitism nor parasitoid emergence when the two agents were used together. Improvements in their combined activity could include better timing and greater frequency of applications, varieties of wheat and barley with more open leaves, and/or formulations of conidia that permit better exposure of the target insect to the fungus.

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Mesquita, A., L.A. Lacey, G. Mercadier, and F. Leclant. 1996. Entomopathogenic activity of a whitefly derived isolate of *Paecilomyces fumosoroseus* (Deuteromycotina: Hyphomycetes) against the Russian wheat aphid, *Diuraphis noxia* (Homoptera: Aphididae) with the description of an effective bioassay method. (In press)

Biological Control

Mission: The mission of the Biological Control program at Newark is to develop strategies for the effective, safe establishment of exotic natural enemies of the RWA through investigation of genetic, demographic, and ecological factors that could prevent establishment and reduce efficacy of natural enemies introduced to control pests.

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Report:

Transfer from Montpellier, France - Hopper, Kazmer, and Ramualde-Serviat transferred to Newark in December 1994. Facilities were renovated to create a general-use laboratory and an incubator room with six reach-in plant growth chambers. Fifteen cultures of *Aphelinus* spp. were successfully transferred from Montpellier. A two-room facility for conducting molecular biological studies of insect natural enemies and pests was established. Specific capabilities include polymerase chain reaction (PCR) amplification of DNA, DNA and protein electrophoresis, protein isoelectric focusing, and digital image acquisition and analysis of electrophoretic results. A video image analysis system for computer-based, real-time acquisition of insect movement patterns was established. Equipment and software were also purchased and set up for capture and analysis of still images for morphometric studies and sample counting. An atomic absorption spectrometer, fume hood, and ultra-microbalance were acquired and set up for trace element analysis in mark-recapture experiments. A local area network was set up to connect newly acquired and extant computers. The LAN was connected to the University of Delaware network to provide direct, high-speed access to local and Internet resources.

Drift, Selection, and the Effects of Long-Term Laboratory Rearing on Fitness Components in the Aphid Parasitoid *Aphelinus asychis* (Hymenoptera: Aphelinidae) - The focal species of this study was *Aphelinus asychis*, a parasite of the RWA. A key feature of our experimental design for this project was the use of replicate cages founded from a common gene pool; this design allows us to distinguish between random changes in fitness components, which may arise due to drift, and unidirectional changes, which are consistent with the effects of selection. In one experiment, we compared replicate cages started in the fall

of 1992 (F_{47}) and 1993 (F_{29}) to material collected in France in May 1995. We found no unidirectional changes in fitness components after 29 and 47 generations of laboratory rearing. However, we did find significant variation among replicate cages of the same age in five of seven cases. In a second experiment, we examined random amplified polymorphic DNA (RAPD) variation within and among the replicate cages. Analysis of 64 RAPD loci showed significant "drift" among cages of the same age, and the degree of drift was greater after 47 generations than after 29 generations. In a third experiment, we estimated the heritabilities of four fitness components using a standard half-sib analysis. Heritabilities for the four fitness components were low (6.3-11.1%). Our main conclusion is that drift may be a more important cause of fitness component change than selection in laboratory rearings of natural enemies. For traits with such low heritabilities as ours, high selection intensities would be necessary for selection to overcome the effects of drift.

Variation in Fitness Components Among Cultures from Geographically Isolated Populations of the Aphid Parasitoid *Aphelinus asychis* - We completed a project on genetic variation in fitness components within and among populations of *A. asychis*. The fitness components we chose to measure were egg load, adult longevity, and walking speed. These are traits likely to affect the success of this parasitoid at finding and parasitizing large numbers of its host and thus are traits likely to be important for biological control. Egg load (i.e., the number of eggs carried by adult females) and adult longevity are particularly important for aphid parasitoids whose hosts are extremely patchily distributed. To be effective in biological control, aphid parasitoids must carry enough eggs to parasitize large numbers of hosts when they encounter an aphid colony, but they must also be able to survive long periods without encountering hosts. *A. asychis* searches for hosts and mates primarily on foot, thus high walking speed is also likely to be important for finding hosts and thus for impact as a biological control agent. We measured hind tibia length (a surrogate for body size) because the above fitness components sometimes scale with body size. Thus, we could control for variation in body size when examining variation in fitness components. We also measured wing size because our observations had confirmed the literature concerning the presence of individuals with very small wings in this species, and we wanted to test whether wing size varied among populations. None of several fitness components (egg load, walking speed, and longevity) varied significantly among cultures of *A. asychis* from collections in China, Kazakhstan, France, Greece, Morocco, and Spain. This was true both for pure cultures and for crosses among cultures. However, all of these components varied significantly among families within cultures. Body size, as measured by hind tibia length, did not vary significantly among cultures or crosses, nor did variation in body size explain significant variation in the fitness components measured. Wing size, as measured by forewing area, did vary significantly among

cultures and crosses, and was affected by body size differently depending on the culture or cross. For egg load, longevity, and walking speed, collection at one geographical location would have provided as much genetic variation as collections from throughout Eurasia.

Aphelinus asychis Sex Pheromone - As part of a project on the effect of numbers released on the success of biological control introductions, we conducted experiments on the rate of the decay and chemistry of the trail sex pheromone produced by adult females of *A. asychis*. To measure the rate of decay of the pheromone, we allowed females to walk on a glass substrate and measured male response to this substrate at various intervals after the females were removed. By 4 hours after removal of the females, male response ceased to be distinguishable from response to clean glass. The pheromone is soluble in ethanol, hexane, and ether, and when redeposited on a glass substrate after dissolution in these solvents, the pheromone will elicit positive male responses. These results reinforce our previous suggestion that males use the trail sex pheromone to find plants on which females are present. That *A. asychis* uses such a method for mate finding suggests that it may be subject to Allee effects at low release rates.

Impact of Natural Enemies on *Diuraphis noxia* in United States and Hungary [Cooperators: Zsuzsa Basky (Crop Protection Station, Szolnok, Hungary), M. J. Brewer (University of Wyoming)] - As part of a series of experiments to measure impact of natural enemies on *Diuraphis noxia* in Eurasia and the United States, we conducted field exclosure experiments in southeastern Wyoming and Hungary. We excluded natural enemies to test whether they prevent increase in *D. noxia* density in wheat. Our approach was to inoculate plants with *D. noxia*; exclude predators, parasitoids, and aphid-born pathogens from some plants and allow access to others; and compare subsequent changes in aphid density by destructively sampling the plants and extracting the aphids in Berlese funnels. In Wyoming, we exposed about 400 aphid-infested plant to one of two treatments: 1) closed cages that completely protect the aphids from natural enemies, half of which had sticky traps, and 2) no cage so that the local community of natural enemies had access to the aphids. We did this in three sites where introduced *Aphelinus albipodus* was found in the summer of 1994 and in three sites where no introduced natural enemies were found previously. We measured predatory density in the surrounding wheat using catch-per-effort techniques, and we will use these densities, together with laboratory data on search and consumption rates, to estimate mortality that could have been caused by predators. We measured parasitoid density in the surrounding wheat by recovering adults from aphid-infested stems placed in emergence canisters. We used the same exclosure treatments in Hungary, but with only one site and no sticky traps. We were unsuccessful at counting the Berlese

samples using an computerized image analysis system, so we are now counting them by hand. When the counts are finished, we will compare the rate of increase and age structure of the aphid population among these treatments using analysis of variance and categorical data analysis.

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